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ABSTRACT

The major objective of this module is to help students understand how water from a source such as a lake is treated to make it fit to drink. The module, consisting of five major activities and a test, is patterned after Individualized Science Instructional System (ISIS) modules. The first activity (Planning) consists of a brief introduction and a series of multiple-choice questions (with answers) related to objectives of activities which follow. Activities 2-4 focus on three different methods for purifying water, including use of activated carbon (activity 2), filtration (activity 3), and chlorination (activity 4) techniques. Procedures, materials needed, and questions are provided for each activity. The final activity is a hypothetical tour through a water treatment plant (using a diagram provided in the module), focusing on the methods used to purify water for human use. The last part of the module is a 15-item multiple-choice test. (JN)

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TIGER
by Bud Blake
WHATCHA DOING, HUGO?
DIGGING A WELL
WHAT FOR?
TO GET CLEAN WATER
HOW CAN WATER BE CLEAN IN THE MIDDLE OF ALL THAT DIRT?
YOU GOT A POINT THERE
BUD BLAKE 7-31

WATER FIT TO DRINK

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SE 5217
Methods of Individualizing Science Instruction
Summer 1980
Instructor - P.B.Horton
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SE040736

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Introduction

This module is all about how water is made fit to drink. We all know that water covers a large quantity of the earth's surface, with most of it being found in the oceans. Unfortunately, sea water is not pure enough to drink because of the salt, so we must primarily get our drinking water from the inland fresh water sources, such as streams, lakes, ponds, rivers, and underground water.

Travelers from countries like the United States are usually advised not to drink the water in less developed nations. This is because, in many regions of the world, water treatment systems are either not present or inadequate. The drinking of polluted (unclean) water can cause illness and even death. We have always felt reasonably sure that our drinking water is of good quality. Unfortunately, in recent years, many people have been questioning the purity of our drinking water. The water coming from faucets in some of our cities has a strong odor, bad taste, and even cloudiness. Many residents have turned to large scale consumption of bottled spring water or have installed special filters in their homes for their drinking needs.

The major objective of this module is to help you understand how water from a source such as a lake is treated to make it fit to drink. We will explore a water treatment plant and try to recreate some of the methods the plant uses to purify the water for human use.

ACTIVITY 1 - PLANNING

This minicourse is different from the others that you have worked with. All the activities are labeled advanced. That's because this entire minicourse is more difficult than the core sections of other minicourses. If you have successfully completed Actions and Reactions or Kitchen Chemistry and have the approval of your teacher, you may proceed with this minicourse. If not, there are many other minicourses that you may attempt.

After doing this planning activity, the other activities must be done in the correct numerical order.

Activity 2

Objective 2-1: What are the uses of activated carbon powder in water treatment?

Sample Question: The two properties of raw water that are treated by the addition of activated carbon powder are

a. minerals

b. color

c. bacteria

d. sludge

e. odor

Objective 2-2: Tell how activated carbon powder removes the color and odor from raw water.

Sample Question: The process by which activated carbon powder removes color and odor from the raw water is

a. chlorination

b. distribution

c. flocculation

d. filtering

e. adsorption

Activity 3

Objective 3-1: Describe the process of filtration and how it helps to purify the water.

Sample Question: The process of filtration helps to purify water by removing which one of the following?

a. minerals causing hardness

b. odor

c. color

d. small particles not trapped earlier

Objective 3-2: Name the 3 materials normally used in the filtration process in water treatment plants.

Sample Question: The three materials generally used in filtration systems are

a. coal

b. shale

c. gravel

d. granite

e. sand

Activity 4

Objective 4-1: State the function of chlorination in water purification.

Sample Question: When chlorine is added to water, it is used to

a. remove odor

b. kill bacteria

c. remove hardness

d. neutralize acids

e. prevent tooth decay

Objective 4-2: Describe the problem that occurs when chlorinated water is left open to the air.

Sample Question: When chlorine is added to water exposed to the air, the effectiveness of the chlorine

a. decreases

b. increases

c. remains the same

Activity 5

Objective 5-1: Explain the steps needed to purify water for drinking purposes from the lake source to your home.

Sample Question: Put the processes used to purify water in the proper sequence, with the first to occur given first and the last to occur last, using the letters.

a. distribution

b. clarification

c. filtering

d. mixing and coagulation

e. fluoridation and chlorination

Objective 5-2: State what chemicals are added to water in order for the water to be purified.

Sample Question: Which of the chemicals below are used in the water treatment process? (indicate all that are used)

a. lime

b. sugar

c. chlorine

d. carbon

e. table salt

Objective 5-3: Identify the main purpose of the different methods used in drinking water treatment.

Sample Question: Match each of the uses of a method of treatment in column B with the method in column A.

A	B
a. Recarbonation	1. prevents tooth decay
b. Coagulation	2. mixes raw water with chemicals
c. Rapid mixing	3. removes color
d. Fluoridation	4. causes small particles to form larger clumps
e. Adsorption	5. lowers water pH

Answers:

2-1. b,e; 2-2. e; 3-1. d; 3-2. a,c,e; 4-1. b; 4-2. a

5-1. d,b,c,e,a; 5-2. a,c,d; 5-3. a-5,b-4,c-2,d-1,e-3

ACTIVITY 2 - SMELLY AND COLORED WATER

In this activity, you will discover how to purify water with activated carbon. You will need the following materials:

1 bottle of food coloring

2 medium size test tubes

1-250 ml beaker

2 medium sized cork stoppers to fit the test tubes

¼ teaspoon of activated carbon powder

1 grease pencil

A. Take two medium test tubes and label them A and B with a grease pencil.

B. Fill each test tube half way with tap water.

C. Use the beaker as a test tube holder.

D. Into test tube A put 3-4 drops of food coloring (enough to make it noticeably blue).

E. Repeat by adding 3-4 drops of food coloring to test tube B. Make up a table in your notebook similar to table 2-1.

2-1. Describe the appearances of test tube contents in A and B in the table under 0 time.

F. Now add ¼ teaspoon of activated carbon powder to test tube A only.

G. Put a stopper in each test tube and shake them at the same time for 30 seconds. Be careful to hold your thumb over the stopper to prevent any spillage of the contents.

H. Let both test tubes sit in the beaker, being careful NOT to shake the contents after this step.

I. Record the appearance of the test tube contents in table 2-1 every 5 minutes for a total time of 30 minutes.

J. Also let the test tubes sit over night. Record the appearance of the tubes the next day.

Table 2-1 Changes in Water Color

	Appearance	
Time (minutes)	Test Tube A	Test Tube B
0		
5		
10		
15		
20		
25		
30		
Next Day		

2-2. Do the contents of the test tubes A and B appear the same after 30 minutes? Do they appear the same after waiting 24 hours?

2-3. If the contents of a test tube changed, state which test tube changed and how long it took to change.

2-4. Why did this activity require you to use two test tubes instead of only one?

2-5. If a change has occurred in one of the test tubes, what has caused the change?

You have probably noticed by now that test tube A is clear on top, with the black carbon powder settling out to the bottom of the tube. Test tube B is still as blue as it was before. Test tube B is a control tube used in comparison to test tube A, so that the change can be attributed to the carbon. If test tube B wasn't present, you would not know if the change was due to the carbon. What has happened is that the carbon, when added to the contents of the tube, created a surface for the molecules of food coloring to attach to. When the carbon settled out because of its weight, the food coloring also settled out. This process is called <u>adsorption</u> and is very effective in removing color from water.

The major reason for color being removed from drinking water sources as it enters a treatment plant is that many people consider it to be objectionable in appearance. The color is caused by substances found in the water from various sources. One of these substances that causes a brown color is tannic acid. Tannic acid is also found in tea and causes

tea to have a brown color. In the lake, the tannic acid comes from plants, while in tea, it comes from the tea plant leaves when hot water is added.

One other advantage of adsorption is that particles that cause odors in the water are also removed by carbon powder. Therefore, the water should be colorless and odorless after this treatment.

2-6. GIVE A DEFINITION OF ADSORPTION IN YOUR OWN WORDS.

ACTIVITY 3 - FILTER YOUR WATER AWAY

In this activity, you will purify water using a process called filtration. You will need a partner for this activity. The following materials are necessary:

5-16 oz cans (with small holes punched in the end and the other end open)
1-500 ml beaker
sand
gravel or large stones (marble size or larger)
5 wide mouth quart jars
5 smaller jars with lids (all the same size)
1 bag or bucket of soil

A. Add enough soil to all of the smaller jars to fill them 1/3 of the way.
B. Add the same amount of water to each jar, leaving a little space at the top for air. Put the tops on the jars.
C. Take the larger quart jars with wide mouths and label them EMPTY, SAND, STONES, FILTER FLOSS OR PAPER TOWEL, AND SAND/STONE.

D. Label each of the 5 cans with the same names as used in C.

E. Shake up one of the smaller jars with soil-water mixture for 1 minute.

F. Take the can and jar with EMPTY written on it. Hold the can so that it is slightly below the edge of the wide mouth jar.

G. Pour the entire contents of the soil-water mixture into the can slowly, recording how long it takes for all the water to run through. Record the time. Save the filtered water in the large quart jar for later.

H. Fill the can marked with SAND half way with sand, fill the STONE can half way with stones, the FILTER FLOSS or PAPER TOWEL can half way, and, finally, the SAND/STONE can with 1/3 sand at the bottom and 1/3 stones on top of the sand. Now repeat prodedures E, F, and G for these other 4 cans.

I. Now line up all of the quart jars and compare them in reference to which is cleanest and which is the least clean. Record these results in table 3-1. Use 1 for cleanest, 2 for next, etc., until 5 for dirtiest.

Table 3-1 Purity Through Filtration

Jar	Filter Material Added	Purity Rating (1-cleanest to 5-dirtiest)	Filter Time (seconds)
1	EMPTY		
2	SAND		
3	STONES		
4	FILTER FLOSS or PAPER TOWELS		
5	SAND/STONE		

3-1. Which filter material cleaned the water the best? Why?

3-2. Which filter material cleaned the water the worst? Why?

3-3. Which filter material did the soil-water mixture go through the fastest? Why?

3-4. Which filter material did the soil-water mixture go through the slowest? Why?

3-5. Which filter material do you consider to be the best overall?

3-6. Is there any advantage to using two materials in a filter rather than one?

3-7. If you were to set up a filter system, what materials would you use? Explain why you would use these materials.

3-8. Water treatment plants try to use materials which filter quickly, but filter cleanly and are inexpensive. Why do you think this is important?

Filtration is one of the most important processes in a water treatment plant because it removes many of the particles that are floating in the water that are not large enough to settle out to the bottom by themselves. In a standard treatment plant, there are several filters as large as a swimming pool which contain 3 layers of filtering material. The layers, from top to bottom, are coal, sand, and gravel. The different sizes of these materials enable different size particles to be removed from the water. The filters obviously collect a lot of material after a period of time, so they must be cleaned periodically by a process called backwash. Water is pumped into the filter tank from the bottom which causes all the filtered material to float to the top, where it is removed. In the meantime, the filter material will settle back because of its weight. The gravel, which is heaviest, will settle first, the sand next, and then the coal. This enables the 3 layers to return to their original position in the filter.

It is well known that paper filters work well in filtering water, but, because they are expensive to replace and clean, they are normally not used.

3-9. GIVE YOUR OWN DEFINITION OF FILTRATION.

ACTIVITY 4 - BYE, BYE BACTERIA

The final water treatment method that we will investigate with an activity is Water Purification with Chlorine. You will need the following materials:

4 medium size test tubes

1-250 ml beaker

1 bouillon cube or beef broth

1-500 ml beaker

1 stirring rod

1 grease pencil

2 cork stoppers to fit the test tubes

2 teaspoons of liquid chlorine bleach

A. Label the 4 test tubes A, B, C, and D with the grease pencil.

B. Fill the 500 ml beaker half way with tap water.

C. Add the bouillon cube to the water in the beaker and stir until it is completely mixed with the water.

D. Fill each test tube half way with the bouillon solution.

E. Into test tube A add 1 teaspoon of additional tap water.

F. Into test tube B add 1 teaspoon of liquid chlorine bleach. Be careful not to spill this on your hands or clothes.

G. Into test tube C add 1 teaspoon of additional tap water. Also, stopper the tube immediately.

H. Into test tube D add 1 teaspoon of liquid chlorine bleach and stopper it immediately. Be careful not to spill the bleach.

I. Put the test tubes in the 250 ml beaker for future observation and place the beaker somewhere where it won't be in the way.

J. Record the appearance of the test tubes in the table under Day 1.

K. Observe and record the changes that occur to the contents of the test tubes over a 5 day period in table 4-1.

L. Put in the table in your notebook the treatment that occurred for each tube.

M. Predict what will happen to the contents of each of the tubes by including this in your table under prediction.

Table 4-1 Bacterial Growth

Treatment - What specific things did you do to each tube to make it different from the other tubes?

Predicted Change - In which tube will spoiling occur - first, second, third, or last? Use 1 for first, and then 2,3, and 4.

Day 1 - Appearance right after preparation.

	Test Tube A	Test Tube B	Test Tube C	Test Tube D
Treatment				
Predicted Change				
Day	Observations			
1				
2				
3				
4				
5				

After the 5th day of observations have occurred, answer the questions below.

4-1. How did your predictions agree with the actual changes in the tube contents? Discuss each tube separately.

4-2. In which tube did spoiling occur first?

4-3. In which tube did spoiling occur second?

4-4. In which tube did spoiling occur third?

4-5. In which tube did spoiling occur fourth?

4-6. Why do you think there were differences between the spoiling in the tubes and to what do you attribute these differences?

4-7. What area of the treatment plant did test tubes A and B represent?

4-8. What area of the treatment plant did test tubes C and D represent?

4-9. How do you think the use of stoppers and chlorine affected the results of this activity?

4-10. Do you think that the chlorination of water is an effective practice? Explain why or why not.

You have probably found out by now that test tube A spoiled first, test tube C, second, test tube B, third, and test tube D, last or not at all. Chlorine is used in treatment plants as a disinfectant. This means that it kills bacteria and, therefore, prevents their growth. Bacteria can be harmful in drinking water by causing certain diseases when consumed by humans. In order to prevent this, the treatment plant adds a certain amount of chlorine to the water at

the end of treatment. The chlorine must be in large enough quantities to have a residual amount at the end of the distribution line, so that the entire water line is free from bacteria. Chlorine that is added to water exposed to the air will eventually escape to the air, enabling new bacteria to grow in the water. The water that has been treated at a plant is usually stored in large storage tanks near the plant or in large water tanks in towers scattered around the town. The underground pipes bring the water to your house. It has been found that, by enclosing the treated water in tanks or pipes, the chlorine will remain effective for a longer period of time. Probably, you now understand the purpose of stoppers in tubes C and D and what they tried to represent.

In test tube A, the spoiling occurred first because it was open to air to permit bacteria to enter and there was no chemical to prevent the growth from occurring. Test tube C was second to spoil because, although no bacteria could get in due to the stopper, there was already bacteria in the bouillon from the water. Also, there was no chlorine to prevent growth. Test tube B was third because bacteria could get in, but the chlorine prevented the growth from occurring until the chlorine escaped into the air. Test tube D shouldn't have spoiled because it was sealed to prevent bacteria from entering and also the chlorine killed any bacteria already present in the bouillon.

4-11. GIVE A DEFINITION OF CHLORINATION IN YOUR OWN WORDS.

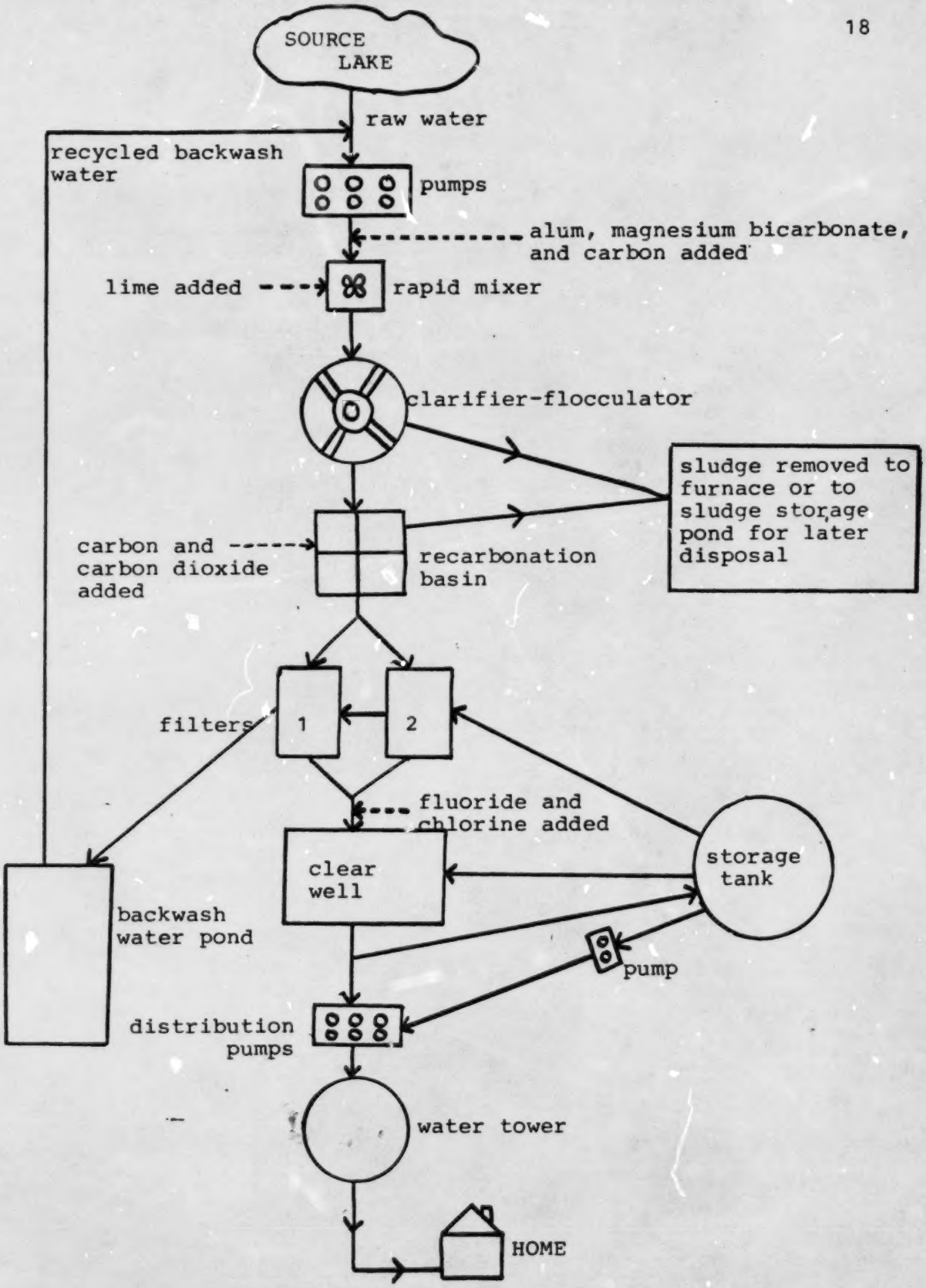

FIGURE 5-1: Drinking Water Treatment Plant

ACTIVITY 5 - TOUR OF A WATER TREATMENT PLANT

Now you are ready to take a tour of a typical water treatment plant. Look at the diagram of the treatment plant in Figure 5-1, and follow the passage of the water from the source to your home, in the discussion that follows.

The water that is in the lake contains fertilizers used in agriculture, minerals from the bottom, compounds from the plant and animal life, such as tannic acid and humic acid, septic tank waste, pesticides used in killing plant life and insects, salt from the ocean carried in the ground water, algae (small green plants), and many other things. This raw water is pumped in, usually from the middle of the lake. Carbon, alum, and magnesium bicarbonate are immediately added to it. The raw water, along with these chemicals, is mixed in a rapid mixer. Also added to the rapid mixer is lime. All of the chemicals except carbon are added to get coagulation and precipitation reactions.

5-1. What is the purpose of the carbon?

5-2. What is the purpose of the alum, lime, and magnesium bicarbonate?

We know that the carbon is added to remove the odor and color. The alum, lime, and magnesium bicarbonate enable the processes of coagulation and precipitation to occur. Coagulation is a process in which certain compounds which cause water hardness to occur are removed. Water hardness is a problem because it causes scale to occur in boilers and water heaters.

It also causes you to use more soap in cleaning. The small particles which do not settle out because of their light weight are clumped together by these chemicals. When the large clumps are formed, they are removed by precipitation, which is a chemical reaction.

5-3. Why do you think that larger particles can be removed easier?

5-4. What is meant by water hardness?

This mixture now enters a clarifier-flocculator, where potato starch or some sticky material is added. The basic purpose of this is to remove the large clumps of particles which have coagulated. The semi-solid material that is removed here is called sludge. The starch was added to speed up the clumping or coagulation process. Flocculation is a process in which the water is stirred or agitated to produce floc (the large clumps of material eventually called sludge when removed from the water). The sludge removed is either burned in a furnace to recycle the minerals left over or it is put in ponds to dry for potential use as fertilizers.

5-5. Why is it that the sludge can be used for fertilizers?

5-6. What is flocculation?

The liquid part from the clarifier-flocculator is sent to the recarbonation basin, where it has carbon powder and carbon dioxide gas added. The carbon will remove any additional odor or color not removed earlier and the carbon dioxide

helps to lower the pH of the water. If you can't remember what pH is, it is simply how acid or alkaline a substance is. Because of the earlier chemicals added, the pH of the water is usually very alkaline. Therefore, the carbon dioxide is added to bring the pH back to the neutral range. Some sludge is removed in the recarbonation basin.

5-7. What is one difference between carbon and carbon dioxide?

5-8. Is the pH of water normally acidic, basic, or neutral?

The water then goes to filters in which the rest of the particles are removed. The filters contain layers of coal, sand, and gravel. Usually these filters can filter 4 to 6 thousand gallons of water per minute. If they become clogged, water is taken from the storage tank and pumped through the bottom of the filters to backwash them. This process removes all of the particles that have been collected by the filters. This backwash water goes to a pond and then it is recycled back with the raw water to be treated.

5-9. What is meant by backwashing of filters?

The water then leaves the filters. Chlorine and fluoride are added. The chlorine kills bacteria and the fluoride is added to help prevent tooth decay.

5-10. Can you think of something else that contains fluoride that helps to prevent tooth decay?

5-11. What is the process of using chlorine in water treatment?

After chlorination and fluoridation, the water goes to a clear well which is a short-term holding tank. The water can then go to the large storage tank on the water treatment plant grounds. It is used when the demand for water is greater than usual. The majority of the time, the treated water goes to the distribution pumps. The water is then pumped to water towers where it can be stored and to your home where it can be used by you for drinking, washing, cooking, swimming, and many other things.

5-12. Why do you think that, in many areas of the country, people must pay for their home water use?

5-13. What are two major factors that would affect the amount of water available for use? One deals with source and the other with the user.

It should be pointed out that not all water treatment plants are the same. In many areas of our country, water does not need to be treated as much as in the plant which you just toured. The number of filters, clarifiers, etc., also varies from plant to plant.

We hope that you have learned something from this tour and have a greater appreciation for what it takes to make water fit to drink.

5-14. Name each of the chemicals added to water being treated and tell what the purpose of each chemical is.

If you have finished all the activities, you should now complete the minicourse test.

WATER FIT TO DRINK

MINICOURSE TEST

Directions: Circle the correct answer on this test booklet.
Choose the one best answer for each question.

Activity 2

1. The use of activated carbon powder in water treatment helps to remove which one of the following from the water?

a. odor

b. bacteria

c. sludge

d. minerals

2. Activated carbon powder removes material from the water by the process called

a. chlorination

b. mineralization

c. adsorption

d. filtration

3. Activated carbon can also be used to remove the ____ from water.

a. oxygen

b. minerals

c. salts

d. color

Activity 3

4. The process which removes small particles in the water by passing through various materials of different sizes is

a. coagulation

b. flocculation

c. filtration

d. chlorination

5. Which of the materials listed below is NOT used in the filtration process?

a. coal

b. gravel

c. shale

d. sand

6. In the process of filtration, there is normally how many different layers of materials used?

a. 1

b. 2

c. 3

d. 4

7. Which of these is NOT an important characteristic of a filter material?

a. inexpensive

b. slow acting

c. solid

d. reusable

Activity 4

8. Chlorine is used in water treatment to primarily control

a. odors

b. bacterial growth

c. hardness

d. tooth decay

9. Chlorine is least effective in water when the water is left in

a. water towers

b. distribution pipes

c. storage tanks

d. open swimming pools

10. Chlorine is normally added to the water in the treatment plant

a. at the beginning, to the raw water

b. during filtration

c. just before distribution and storage

d. during flocculation

Activity 5

11. In the purification of water, fluoride is usually added before distribution to

a. kill bacteria

b. prevent tooth decay

c. lower pH

d. remove small particles

12. Which of these is NOT a chemical used in water treatment?

a. carbon

b. carbon dioxide

c. table salt

d. chlorine

13. The two processes involved in the removal of sludge from treated water are

a. recarbonation-flocculation

b. filtration-recarbonation

c. distribution-flocculation

d. filtration-distribution

14. Which chemical below is used in the coagulation process?

a. fluoride

b. carbon dioxide

c. chlorine

d. alum

15. One major problem of raw water is its hardness, which can cause

a. diseases and even death

b. excessive use of soap in washing

c. increased growth of bacteria

d. tooth decay

Test Answers

1-a, 2-c, 3-d, 4-c, 5-c, 6-c, 7-b, 8-b, 9-d, 10-c, 11-b, 12-c, 13-a, 14-d, 15-b